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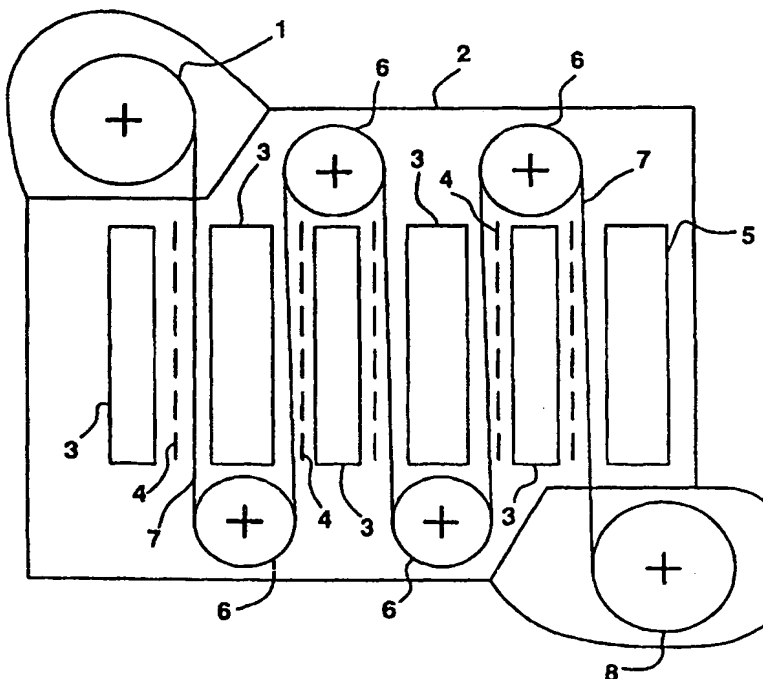
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(54) Title: MICRO-FUEL CELL POWER DEVICES

(57) Abstract

Coupling miniature liquid fueled fuel cells (27) with portable electrical devices (12), with or without rechargeable batteries (34), lead to new appliance configurations: charging holster (11), piggyback charger (26), fuel cell (27) integral with rechargeable battery (34), fuel cell with voltage regulating electronics (73), supplying fuel through a tube (71) with a valve (72) or pump (41), and supplying power through an electric cable (74) between the fuel cell (27) and the electronic device (12) and the fuel cell power pack (84). There may be a window (24) showing the fuel level (105) of a disposable fuel ampoule (29) or refillable tank. Fuel is distributed through disposable fuel ampoules (29) in blister packages (23), or refueling bottles. These design features permit greater performance, workability, and convenience to the user of these portable electronics (12). Additionally, these micro fuel cell arrays (19), may be mass produced on a plastic film (7) in a reel to reel process.



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Micro-Fuel Cell Power Devices

BACKGROUND OF THE INVENTION

The present invention relates generally to fuel cell devices, and more specifically to the manufacturing process for MICRO-FUEL CELL™ power devices and to their application configurations.

A number of miniature fuel cells suitable for use with portable electronic products are becoming available today, but less attention has been shown to the low-cost mass production and device packaging of these fuel cells for varied applications. There is limited information in the literature concerning such things as the coupling of these miniature cells to the various applications, methods for refueling the cells in a low-cost and efficient manner, or any type of thermal insulation to elevate the temperature of the cell for higher efficiency in various environmental conditions. Another problem with portable electronic appliances is that they need to be kept in a ready position that is secure but easily accessible when needed. For example, cellular phone holsters may use clips and gravity securing devices to keep the phone from dropping when jostled. Another problem with portable electronics is that they can easily be misplaced.

Representative prior inventions of this general type include U.S. Patents 5,364,711 and 5,432,023, which describe miniature fuel cells that run on methanol and are used to run electronics, and U.S. Patents 4,673,624 ("Fuel Cell") and 5,631,099 ("Surface Replica Fuel Cell"), which describe methods of forming fuel cells. None of those patents describe how to package the fuel cell to efficiently run the electronics applications. U.S. Patent 5,759,712 ("Surface Replica Fuel Cell for Micro Fuel Cell Electrical Power Pack") describes how a fuel cell can be packaged in a general hybrid systems power pack which may be comprised of a fuel cell and other energy sources, such as a battery, flywheel, or solar cells. It mentions cellular phones in particular, but does

not appear to describe the coupling configurations or refueling systems for these electrical applications. In this application, the porous gas manifolds and air gaps in the case of the power packs acts as both insulation and water control mechanism. None of those patents mentioned using exchangeable insulation to compensate for different environmental temperature conditions. However, none of those patents discloses or suggests the novel features of the present invention.

SUMMARY OF THE INVENTION

The present invention applies the fuel cells described in this inventor's U.S. Patents, 4,673,624, 5,631,099, and 5,759,712, to numerous electrical devices. Examples of devices that realize a significant advantage from such power systems include, but are not limited to, portable electronics and power tools; such as cellular phones, pagers, video camcorders, portable tools, portable PCs, portable toilets, smoke detectors, hearing aids, portable stereos, portable TVs, portable radios, night vision goggles, portable lighting, toys, computer peripherals, and portable vacuum cleaners.

The critical component in this invention is a fuel cell that is formed on a plastic sheet, including a number of fuel cells described in "Surface Replica Fuel Cell", U.S. Patent 5,631,099, U.S. Patent 4,673,624, and U.S. Patent No. 5,759,712. These fuel cells pack more energy in a smaller space than conventional rechargeable batteries by utilizing liquid methanol and water fuel. The methanol fuel has effectively 5 to 13 Whr per cubic inch (20% to 50% efficiency) energy density. This is 3 to 9 times the energy density of today's best nickel cadmium batteries, and 40 to 120 times that of standard cellular phone battery packs. These micro-fuel cells are lighter than conventional rechargeable batteries. The methanol fuel has effectively 1200 to 3000 Whr per kg energy per unit mass (20% to 50%

efficiency). This is 2 to 5 times the 600 Whr per kg quoted for the latest rechargeable lithium ion batteries (Science News, March 25, 1995).

Our first micro-fuel cell is designed to replace the standard cellular phone battery packs. Conventional cell phones usually have a warning alert signal when the battery is low, but the accuracy and dependability of these indicators often leave much room for improvement. Determining the remaining energy capacity from a rechargeable battery typically uses the voltage output level as an indicator of charge but does not measure the capacity. Therefore, history of the discharge is used to assess the future of the remaining output. This electronic assessment of remaining energy capacity is complex, requires diagnostic electronics and is prone to errors. The liquid fueled fuel cell eliminates this uncertainty. Checking the fuel supply is as simple as looking at the liquid level in the fuel tank. The amount of fuel remaining compared to the total fuel tank capacity is the fraction of the total energy. Refueling also provides instant recovery. Components of these micro-fuel cells are inexpensive. Manufacturing and assembly cost are low. The production techniques allow the fuel-cells and power supply systems to be manufactured at costs similar to rechargeable batteries. The production techniques enable the fuel cells to be produced in a roll-to-roll manufacturing method, similar to printing press processes. The production is envisioned as taking place in a vacuum system in which the metal electrodes and catalysts are deposited onto a reeled plastic web. The electrolytes may also be deposited by means of a reeled vacuum deposition system or dip tank. The individual fuel cell devices would be cut off the rolls of fuel cells and assembled. The edge seals are expected to be heat seals, with the cutting operation and heat seal operation envisioned as one and the same. The MICRO-FUEL CELL is the "green" (environmentally clean) solution to energy needs. It is never thrown away, but rather refueled

with common ethanol or methanol, an abundant and renewable energy source. The production process and the disposal of manufacturing by-products do not present toxic waste problems. The plastic fuel tanks when empty can be disposed of as common food packaging.

One aspect of this invention addresses the fact that small portable fuel cells encounter a range of exterior environmental temperature and humidity. To compensate for this range and to optimize the performance of the fuel cells an adjustable moisture and thermal internal insulation barrier is used to allow fuel cells to run at elevated temperatures.

Current appliances that run on rechargeable batteries are recharged by "plugging in" to alternating current sources or DC electrical systems, such as found in a car or other vehicle. This source of energy may be inconvenient or unavailable for many users in remote locations. The present invention allows the fuel cell energy system of an appliance, the fuel cell itself, and the fuel supply packaging to all fit together in a convenient manner.

These and further and other objects and features of the invention are apparent in the disclosure, which includes the above and ongoing written specification, with the claims and the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1A is a schematic representation of the reel-to-reel web coating production process for the micro-fuel cells of this invention.

Figure 1B is a flow chart of the back-end production process for the micro-fuel cells of this invention.

Figure 2A is a perspective view of the cellular phone power holster of this invention.

Figures 3A and 3B are perspective views of a fuel tank and a blister pack of fuel tanks.

Figures 4A and 4B are front and side elevations of a cellular phone with a ratchet mechanism.

Figures 4C and 4D are front and side elevations of a holster for receiving a cellular phone with a ratchet mechanism.

Figures 5A and 5B are perspective views of a piggyback charger.

Figures 6A and 6B are an exploded view of a trickle charger and a perspective view of a trickle charger.

Figures 7A and 7B are perspective views of refilling a trickle charger and a refillable trickle charger battery.

Figures 8A and 8B are an exploded view of a cellular phone with a fuel cell and a perspective view of a cellular phone with a fuel cell in place.

Figure 9 is a perspective view of a fuel ampoule.

Figure 10 is an exploded view of a desk power charger.

Figure 11 is an exploded view of a battery charger doughnut.

Figure 12 is an exploded view of a portable computer fuel-cell power supply.

Figure 13 is an exploded view of a portable camcorder piggyback fuel-cell power supply.

Figure 14 is an exploded view of an external fuel-cell power supply for a portable battery-powered device.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 1A shows a preferred embodiment of the production process for the MICRO-FUEL CELL of the present invention. The production line starts with a porous plastic substrate manufactured, as described in U.S. Patent 5,631,099, in which the plastic is irradiated and etched to produce patterned porous plastic films. Alternatively manufactured porous plastic films may be used where selective areas of pores are filled to produce non-conductive regions in the MICRO-FUEL CELL arrays. The porous plastic web 7 is rolled onto a source reel 1 (spool) and inserted into the web coating

vacuum chamber 2. Several loading schemes are available. The plastic web 7 may be reeled into the vacuum chamber 2 through a differential pumped seal, inserted through a load lock, or inserted into the coating chamber in an air environment and then evacuated. The plastic web 7 is reeled past the sputter sources and evaporation sources (guns) 3, as shown, where deposition patterns are deposited in any one of a variety of ways, as follows:

- i) the first scheme, shown here, is to sputter through proximity sputter masks 4;
- ii) the second scheme is to raster an atomic beam of the deposit material; or
- iii) the third way is to use self masking patterns on the porous plastic substrate and a deposition source which has angle of incidence and collimation control.

An analogous system of deposition in air or liquid includes spray painting, ink jet printing, proximity electroplating, Xerography, photolithography, chemical vapor deposition and auto electroplating, which all may be used in a reeled web system, under vacuum, controlled atmosphere, or in air as appropriate to the deposition requirements. All these deposition techniques are mentioned in U.S. Patent 5,759,712. In the vacuum deposition system, a variety of sputter sources 3 and heat sinks 5 may be arranged parallel to the porous plastic web 7. The production output rate of this sputter system is critically dependent upon the maximum temperature at which the materials are deposited onto the plastic substrate, and the rate at which heat is removed by means of strategically placed heat sinks 5. The heat removal from the plastic substrate in the vacuum system is proportional to the forth power of the absolute temperature and it's emisivity. The sputter sources 3 remove all excess heat transfer to the plastic substrates, but the essential heat input will come from the heat of condensation of the deposit material. Thus, the heat input to the plastic

substrate is essentially proportional to the rate at which material is deposited. The deposition dwell time for a coating is proportional to the thickness of the film and the material condensation enthalpy divided by the desired substrate temperature to the forth power. The porous plastic web 7 may be moved into position using encoded motors on the position rollers 6. The fundamental motions are to:

- i) advance the plastic film;
- ii) fine adjust the position; and then
- iii) dwell for the deposit.

The positioning of the plastic web is coordinated through optical sensors to marks on the porous plastic or to the first deposit pattern. Slack in the plastic film between sputter deposits can be compensated for by translator controlled take-up reels. The first step in the material deposit is an oxygen ion milling of the surface of the plastic. Surface texturing may also take place in this step. Examples of material deposited in order are:

For the fuel side of the membrane:

- i) high pressure sputter Pt/Ru to form porous deposits;
- ii) low pressure sputtered Pd; and
- iii) high pressure sputtered Pt/Ru.

For the air side of the membrane:

- iv) low pressure Au; and
- v) high pressure Pt/Ru.

Thus, in this example, five sputter guns 3 and deposits would be used to deposit the electrodes. The porous plastic web 7 is taken up on a take-up reel 8 which is aft of the sputter guns 3. The plastic film 7 may exit from the sputter chamber 2 by any one of the methods as previously mentioned to insert the plastic film.

Figure 1B shows the back-end process for manufacturing the MICRO-FUEL CELLS. From the coating chamber 2, the plastic film 7 is loaded into an electrolyte coating system 9 (unless the electrolyte was already deposited in the vacuum

chamber since some electrolytes can be deposited in vacuum.) The plastic web 7 is next reeled through an electrolyte solution, such as 5% Nafion[®] solution (perfluorinated ion exchange polymer alcohol solution made by Solution Technology Inc, PO Box 171 Mendenhall, PA. 19357), and then is drawn up through a drying and heat curing oven 10 to provide the finished plastic web 101. Finally, the plastic web is then assembled with the gas manifolds, as in U.S. Patent 5,759,712. The gas manifolds and a diffusion membrane or a second fuel cell array sub-assembly may be assembled and heat sealed, ultrasonic welded, or glued around the rim in place on the plastic web. These assembled MICRO-FUEL CELL arrays are then reeled onto spools which can be shipped to separate locations or cut out of the plastic web immediately. Laser cutting, shear cutting or die cutting are used to slice out the fuel cell arrays from the plastic web. The cutout fuel cell arrays are placed in the fuel cell assemblies as described in U.S. Patent 5,759,712 and the remainder of this patent. The fuel cell power supply assemblies then undergo an electronic performance check after they are assembled.

Figure 2 shows a power holster 11 that is formed with a polycarbonate plastic housing to fit snugly around a cellular phone 12. The cellular phone 12 needs to fit such as to maintain positive pressure between its electrical contacts and those in the power holster through gravity and the vertical mounting of the cellular phone. Alternatives to using gravity pressure is to have the phone press against electrical spring contacts 13 or to snap-in with a ratchet mechanism 14, as shown in Figures 4A, 4B, 4C and 4D. The ratchet 14 is released by applying pressure simultaneously to the finger buttons 15, located in the ratchet holes 16 on each side of the fuel cell holster 11. Alternatively, the mechanism's ratchet teeth 18 may be designed with a slope on both sides, so that the phone is removable from the holster by means of a firm pull. Velcro attached at the bottom of the holster is another securing mechanism working with the

springy electrical contacts 13. To provide a means of attaching the power holster to clothing, a clip 103 may be formed in the power holster plastic housing 11. An alternative is to form a belt loop to permit a belt or purse strap to be threaded through.

Referring back to Figure 2, the MICRO-FUEL CELL array 19 is placed along the length of the polycarbonate plastics housing 11. A gas diffusion mat 20, made from polyester fiber paper to serve as a protective cover, is placed over the MICRO-FUEL CELL array 19. The gas diffusion mat 20 also serves as a thermal insulation layer. In cold environments it may be made thicker and in hot environments it may be thinner to maintain an optimum elevated operating temperature of the fuel cell array 19. The power holster 11 has a fuel cavity 21 designed to accept the fuel tanks 22, shown in Figure 3A. The fuel tanks 22 are made from polyethylene plastic and filled with 1:1 molecular ratio of methanol to water mixture. The fuel tanks 22 are inserted into the fuel cavity 21 and are impaled on the fueling needle (not shown) to start fueling. The fuel is then wicked from the needle to the MICRO-FUEL CELL fuel manifold. The fuel tanks 22 may be sold in blister packages 23, as shown in Figure 3B. To allow observation of the fuel level 105 in the fuel tank 22 while mounted in the power holster 11, a window 24 is included in the plastic housing over the fuel tank. Other methods of measuring fuel level include:

- i) a weight monitoring system correlated to fuel quantity based on the fact that the device will get lighter as the fuel is depleted is a viable alternative;
- ii) measuring the electronic capacitance of the fuel tank by placing electrodes in close proximity to the tank;
- iii) adding a chemical colorant that changes color or opacity as the fuel is depleted;

- iv) a fuel immobilizer matrix in the fuel tank, such that when fuel is replaced with gas it's opacity will change; and
- v) in larger systems, a float indicator such as fuel gauge systems in vehicles.

Electric power from the MICRO-FUEL CELL 22 is delivered to the electrical contacts 107 on the cellular phone through two gold coated beryllium copper contact leaf springs 13 that make contact with the MICRO-FUEL CELL 22 through rivet or other electrical connections. Additional electronic functions and features that may be incorporated into the holster 11 include:

- i) a locator device, consisting of a receiver/transmitter being added to the holster so that when the cell phone is misplaced it may be located by means of a directional antenna or by simply stimulating the ringer on the phone;
- ii) a pager feature from the holster to the phone could be added;
- iii) a portable computer that can use the portable phone or electronic device as its communication relay;
- iv) a radio communications relay transmitter for a portable communication device which thereby reduces the weight and mass of the portable communication device; and
- v) such a portable communication device has the potential to be reduced to the size of a wristwatch, two-way hearing aid (bone conduction microphone), credit card or broach, so as to be located in a purse; pocket, attached to the belt, shoes, or inside the body as long as it can receive sufficient oxygen.

The piggyback charger 26 is formed with a polycarbonate plastic housing 25 to fit snugly and have a positive gripping hold around a cellular phone 12, as shown in Figures 5A and

5B. A positive grip on the phone 12 may be accomplished in a number of ways, including:

- i) using Velcro foam backed strips in the well of the plastic housing;
- ii) by rubber ratchets on the inside of the plastic housing and a foam pad in the well of the housing; and
- iii) with ratchets that extend around the end of the phone.

The MICRO-FUEL CELL array 27 is placed along the length of the polycarbonate plastics housing 25, as shown. A gas diffusion mat 28, made from polyester fiber paper to serve as a protective cover, is placed over the MICRO-FUEL CELL array 27. The gas diffusion mat 28 also serves as a thermal insulation layer. In cold environments it may be made thicker and in hot environments it may be made thinner to maintain an optimum elevated operating temperature of the fuel cell array 27. The mat 28 or matrix may be wetted or coated with a wetting agent that causes water to be wicked into the fuel cell 27 to maintain an optimum humidity on the fuel cell. The surface energy or wetting coatings may be varied though the thickness of the matrix to draw water back into the fuel cell 27. One alternative is to use hollow fibers in the matrix and by capillary action draw condensed water into the fuel cell 27. For applications where there is excessive heat and water production, this same wicking system may be used to remove the excessive heat and water. The vaporization of water and liquid return cycle acts as an additional cooling mechanism for the removal of heat. If there is condensed water in the matrix, it increases the thermal conductivity, which reduces the thermal insulating property of the matrix, and raises the outer temperature of the matrix, thereby vaporizing more water to the outside air. The piggyback charger 26 has a fuel cavity designed to accept the low profile sealed fuel tank ampoule 29 between the insulating mat 28 and the cellular phone 12. The fuel tanks

29 are shaped to fit the tank cavity and are made from polyethylene plastic and filled with 1:1 molecular ratio of methanol to water mixture. Other fuel mixtures of methanol and water may be used, as well as other types of alcohols, hydrocarbons and hydrogen bearing compounds. The fuel tanks 29 are inserted into the fuel cavity and are impaled onto the fueling needle to start fueling. The fuel is then wicked from the needle to the MICRO-FUEL CELL fuel manifold. The fuel tanks 29 may be sold individually or in volume packages. To allow observation of the fuel quantity while the tank is in the piggyback charger 26, a transparent window over the fuel tank is included in the plastic housing 25 for direct viewing of the fuel level. The electric power from the fuel cell 27 is delivered to the charging contacts 107 on the cellular phone through two gold coated beryllium copper contact leaf spring contacts (not shown). These contact springs make contact with the MICRO-FUEL CELL 27 through rivet or other electrical connections. The piggyback charger 26 is designed to be carried as an integral part of the phone so as to continuously charge the cell phone's battery. The cell phone 12 is fully functional at all times, even with the piggyback charger 26 in place. The piggyback charger 26 may have an outer porous cover to permit moisture from the fuel cell 27 and the user's hand to evaporate. The porous cover may also enhance the user's grip on the phone and make it more comfortable to use. The piggyback charger 26 does not cover any of the cellular phone function buttons 109, antenna 111, or displays 113.

As shown in figures 6A and 6B, the trickle charger 30 is formed with polycarbonate plastic housing to fit in the position designed for batteries in a typical cellular phone 31. The trickle charger 30, which replaces the standard battery pack in a cell phone 31, has four primary components:

- i) a fuel cell 32;
- ii) a fuel tank 33;

iii) a battery 34 (shown in this example as a lithium battery); and

iv) an insulation mat 35.

The MICRO-FUEL CELL array 32 is placed along the length of the polycarbonate plastics housing, as shown, and used to provide a continuous trickle charge to the battery 34. A gas diffusion mat 35, made from a matrix material such as polyester fiber paper to serve as a protective cover, is placed over the MICRO-FUEL CELL array 32. The gas diffusion mat 35 also serves as a thermal insulation layer. In cold environments it may be made thicker and in hot environments it may be made thinner to maintain an optimum elevated operating temperature of the fuel cell array 32. The heat from the fuel cell 32 warms the trickle charger 30 and maintains a higher operating temperature on the battery. For very cold environments the gas diffusion mat insulation 35 covers both the battery 34 and the fuel cell 32 to keep the battery at an elevated temperature from the surroundings. For warm environments the fuel cell 32 may be insulated from the battery 34, and both the battery and fuel cell have minimal insulation to the exterior of the case. A material that is commercially available to do this function is called CoolMax® (made by Bush Associates P.O. Box 3043, Newport, CA 92663). To enable the fuel cell 32 to handle a range of temperature conditions the insulation may have a different thickness across each of the fuel cells in the array 32. When the fuel cell array 32 is idling, the well insulated portion of the array is operating at optimum temperature and humidity while the less insulated portion of the fuel cells are cooler and at sub-optimum temperature. When the MICRO-FUEL CELL 32 is under load or in higher environmental temperatures, the insulated portion of the array is dehydrated and sub-optimum and the less insulated portion is at optimum temperature and humidity. The fuel cavity is designed to accept sealed fuel tanks (ampoules) 33 inserted between the cellular phone and the trickle charger 30. In

another embodiment, shown in Figure 6B, the fuel ampoule 33 is snapped into the back of the trickle charger 30 while it is attached to the cellular phone 31. The fuel tanks 33 are shaped to fit the tank cavity and are made from polyethylene plastic and filled with 1:1 molecular ratio of methanol to water mixture. As the fuel tanks 33 are inserted into the fuel cavity they are impaled onto the fueling needle (not shown) to start fueling. The fuel is then wicked from the needle to the MICRO-FUEL CELL fuel manifold. A ratcheting, positive clamping, snap-in, or other containment of the fuel tank 33 is provided between the trickle charger 30 and the fuel tank. The fuel tanks 33 may be distributed individually or in volume quantities. To allow observation of the fuel level in the fuel tank 33 while attached to the trickle charger 30, a transparent window (not shown) over the fuel tank is included in the plastic housing for direct viewing of the fuel level. Electric power from the fuel cell is delivered to the charging contacts on the cellular phone through two gold coated beryllium copper contact leaf spring contacts (not shown). These contact springs make contact with the MICRO-FUEL CELL 32 through rivet or other electrical connections. The trickle charger 30 is carried as an integral part of the phone 31, making the phone fully functional at all times. The trickle charger 30 may have an outer porous cover to permit moisture from the fuel cell 32 and the user's hand to evaporate. The porous cover enhances the user's grip on the phone and makes it more comfortable to use. The trickle charger 30 does not cover any of the cellular phone function buttons 115, antenna 117, or displays 119.

The refillable trickle charger 121, shown in Figures 7A and 7B, is formed with polycarbonate plastic housing 36 to fit in the position designed for batteries in the cellular phone 31. The refillable trickle charger 121 has four primary components:

- i) a fuel cell (not shown);

- ii) a molded in fuel tank 38;
- iii) a refueling tank or dispenser 39; and
- iv) a battery 40 (shown in this example as a lithium battery).

The MICRO-FUEL CELL array (not shown) is placed along the length of the polycarbonate plastics housing 36. A gas diffusion mat (not shown), made from polyester fiber paper to serve as a protective cover, is placed over the MICRO-FUEL CELL array. The gas diffusion mat also serves also a thermal insulation layer. In cold environments it may be made thicker and in hot environments it may be made thinner to maintain an optimum elevated operating temperature of the fuel cell array for maximum efficiency. The heat from the fuel cell warms the trickle charger 121 and maintains a higher operating temperature on the battery 40. For very cold environments, in addition to the gas diffusion mat, both the battery 40 and the fuel cell provide more insulation to help keep the battery at an elevated temperature from the surroundings. On the other hand, for warm environments the fuel cell may be insulated from the battery and both the battery and fuel cell may have minimal insulation to the exterior of the case. The fuel cavity is designed to have the fuel tank 38 molded in between the cellular phone 31 and the trickle charger 121, as shown. The fuel tank 38 is shaped to fit the tank cavity and may be made from PET polyethylene terephthalate or a similar plastic. The fuel tank 38 is filled with 1:1 molecular ratio of methanol to water mixture from a fuel dispenser 39. A refillable port 41, with a built-in valve that opens for refueling, is located on the side of the trickle charger 121. The valve may be a spring loaded type, such as a tire valve, or a mechanism such as a rubber seal in a basketball where filling is accomplished with a needle through the seal. The act of refueling may be an alternate squeezing and relief action that forces the fuel from the dispenser 39 into the tank 38, while at the same time releasing gas pressure in the tank.

The fuel dispenser 39 may have any one of a number of insertion tip features, including, but not limited to:

- i) it may seal to the valve on the trickle charger;
- ii) it may screw into the trickle charger;
- iii) it may twist-lock and seal into the trickle charger; and
- iv) in a dual flow manner, it may provide an exit route for gas in the fuel tank as fuel is flowing in.

In refueling, the fuel is wicked from the needle 37 to the MICRO-FUEL CELL fuel manifold. The fuel dispensers 39 may be distributed individually or in blister packages, or they may be refillable through a screw cap from larger bottles of fuel. To allow observation of the fuel level in the fuel tank 38, a transparent window (not shown) is included over the fuel tank and built into the side of the plastic trickle charge refill housing 36. The electric power from the fuel cell is delivered to the charging contacts on the cellular phones through two gold coated beryllium copper contact leaf spring contacts. These contact springs make contact with the MICRO-FUEL CELL through rivet or other electrical connections. The trickle charge refill 121 is designed to be carried as an integral part of the phone. The trickle charger refill 121 may have an outer porous cover to permit moisture from the fuel cell and the user's hand to evaporate. The porous cover enhances the user's grip on the phone and makes it more comfortable to use.

Referring to Figures 8A and 8B, the fuel cell only power supply is formed with a polycarbonate plastic module 42 to fit in the position designed for batteries in the cellular phone 31. The fuel cell has four primary components:

- i) a fuel cell 44;
- ii) a large capacity fuel tank 45;
- iii) an insulation and diffusion mat 46; and
- iv) voltage regulating electronics (not shown).

The MICRO-FUEL CELL array 44 is placed along the length of the polycarbonate plastic module's housing 42, as shown in

Figure 8A. A gas diffusion mat 46, made from polyester fiber paper to serve as a protective cover, is placed over the MICRO-FUEL CELL array 44. The gas diffusion mat 46 also serves as a thermal insulation layer. In cold environments it may be made thicker and in hot environments it may be made thinner to maintain an optimum elevated operating temperature of the MICRO-FUEL CELL array. The fuel cavity is designed to have fuel tank 45 between the cellular phone 31 and the plastic housing 42, as shown. The fuel tanks 45 are shaped to fit the tank cavity and are made from polyethylene plastic and filled with 1:1 molecular ratio of methanol to water mixture. The fuel tanks are inserted into the fuel cavity and are impaled onto the fueling needle (not shown) to start fueling. The fuel is then wicked from the needle to the MICRO-FUEL CELL fuel manifold. The fuel tanks 45 may be sold individually or packaged in volume quantities. The fuel tanks may also be refilled from a larger container of fuel by means of screw cap. To allow observation of the fuel level, a fuel level indicator window 47 is included in the side of the fuel cell module's plastic housing 42. Electric power from the fuel cell is delivered to the charging contacts on the cellular phone through two gold coated beryllium copper contact leaf spring contacts. These contact springs make contact with the MICRO-FUEL CELL through rivet or other electrical connections.

The fuel-cell-only is designed to be carried as an integral part of the cell phone. The fuel-cell-only may have an outer porous cover to permit moisture from the fuel cell and the user's hand to evaporate. The porous cover enhances the user's grip on the phone and makes it more comfortable to use.

The fuel tanks or ampoules 48 are sealed polyethylene containers filled with a 1:1 molecular mixture of methanol and water, as shown in Figure 9. The container wall material and properties are chosen to retain the fuel mixture at least five (5) years with less than a 10% loss of fuel. A dimple

49 which may be punctured with a needle is included for fueling the ampoule 48. The surface 123 where the sealing dimple is located needs to be smooth and impermeable enough to permit an o-ring or other type seal to fit tightly around the fueling needle, or mechanism. Other than the dimples, the container may have ridges or protrusions that allow it to fit into the particular fuel cell device and maintain structural integrity to assure a reliable seal with the fueling needle from full to empty. The fuel ampoules 48 may have shapes and forms that allow them to fit snugly and fill the available space in the power supply cavity of a product. The fuel ampoules 48 may be filled with a fuel permeable material that allows the fueling needle to make wicking contact with the fuel regardless as to the orientation of the fuel tank. The tank filler may also have the property that as the fuel is removed from the fuel tank the filler becomes opaque to light or changes color. The fuel tank filler may also act as a flow retardant to minimize fuel leakage in the event of a fuel tank rupture.

As shown in Figure 10, the desk power charger 51 is used to charge the batteries in a cellular phone 52 when the phone is not in use. This desk power charger 51 is formed with polycarbonate plastic or ABS plastic (terpolymer of acrylonitrile, butadiene, and styrene) into a housing 50 that accepts the cellular phone 52 and holds it snugly in place, as shown in Figure 10. The cellular phone 52 maintains a positive pressure on the electrical contacts in the desk power charger 51 through gravity and/or the vertical mounting of the cellular phone. Alternatives to using gravity pressure is to have the cell phone press against electrical spring contacts and snap-in with a ratchet mechanism, which may be released with a mechanism requiring double pressure on the sides of the charger, or by means of a firm pull on the phone if the ratchet is designed with a slope on both sides of the teeth as discussed earlier with the holster release of Figure 4A. Velcro, screws, or sticky foam tape may be

included on the bottom of the power charger 51 to allow it to be attached to a desk, etc.

The MICRO-FUEL CELL array 53 is placed along the length of the polycarbonate plastic housing 50. A gas diffusion mat 54, made from polyester plastic fiber paper to serve as a protective cover, is placed over the MICRO-FUEL CELL array 53. The gas diffusion mat 54 also serves as a thermal insulation layer. In cold environments it may be made thicker and in hot environments it may be made thinner to maintain an optimum elevated operating temperature of the fuel cell array 53. The desk charger 51 has a large fuel cavity designed underneath to accept the fuel tank (ampoule) 55. The fuel tank 55 is made from polyethylene plastic and filled with 1:1 molecular ratio of methanol to water mixture. As the fuel tank 55 is inserted into the fuel cavity, it is impaled on the fueling needle (not shown) to start fueling. The fuel is then wicked from the needle to the MICRO-FUEL CELL fuel manifold. This larger fuel tank will generally be sold individually or packaged for volume distribution. To allow observation of the fuel level in the fuel tank, a transparent fuel level window 56 is built into the plastic housing 50 of the desk power charger 51.

Electric power from the fuel cell 53 is delivered to the electrical contacts on the cellular phones through two gold coated beryllium copper contact leaf spring contacts. These contact springs make contact with the MICRO-FUEL CELL 53 through rivets or other electrical connections.

The battery charger doughnut or ring 125, shown in Figure 11, is formed with polycarbonate plastic housing 57 to fit snugly with a positive gripping hold around a rechargeable battery 63, as shown in Figure 11. The positive grip on the battery 63 may be accomplished using springy sliding end caps 58 and 59 that also make the electrical connection between the fuel cell 60 and the battery 63. The MICRO-FUEL CELL array 60 is placed along the exterior periphery of the fuel tank 62. A gas diffusion mat 61, made from polyester fiber

paper to serve as a protective cover, is placed around the MICRO-FUEL CELL array 60. The gas diffusion mat 61 also serves also a thermal insulation layer. Gas diffusion 61 mats may be placed on both the exterior and interior sides of the MICRO-FUEL CELL array 60. In cold environments it may be made thicker and in hot environments it may be made thinner to maintain an optimum elevated operating temperature of the fuel cell array 60.

The battery charger doughnut 125 has a fuel cavity which is designed to accept a sealed fuel tank 62 in between the gas MICRO-FUEL CELL array 60 with diffusion mat 61 and a standard battery 63. The fuel tanks 62 are shaped to fit the tank cavity of the charger 57 and have a cylindrical hole in the center to accept a standard rechargeable battery 63. The tanks 62 are made from polyethylene plastic and filled with 1:1 molecular ratio of methanol to water mixture. The fuel tanks are inserted into the fuel cavity and are impaled onto the fueling needle (not shown) to start fueling. The fuel tanks 62 are held in the polycarbonate plastic housing 57 by the electrical end caps 58 and 59 and the polycarbonate housing. The fuel is wicked from the needle to the MICRO-FUEL CELL fuel manifold. The fuel tanks may be sold individually or packaged for volume distribution. To allow observation of the fuel level in the fuel tank 62, a viewing slot 64 is built into the battery charger housing 57. The electric power from the fuel cell 60 is delivered to the charging contacts on the battery 63 through two gold coated beryllium copper contact leaf spring contacts 127 located on the upper 58 and lower 59 end caps. These contact springs 127 make contact with the MICRO-FUEL CELL through rivets or other electrical connections. The battery charger ring 125 is designed to have an external profile that matches the battery space available in an electrical application. The outer surface of the battery charger ring 127 is porous with ventilation holes 65 to permit moisture and carbon dioxide from the fuel cell to diffuse out and oxygen to diffuse in.

The porous cover can be energy absorbing to enhance the mechanical shock absorbing performance of the power supply in the electrical application.

A portable computer fuel cell power supply 66 is formed with ABS plastic housing 127 to fit and attach onto the exterior surfaces of a portable computer 67, as shown in Figure 12. The fuel cell power supply 66 has seven (7) primary components:

- i) a fuel cell array 68;
- ii) a diffusion and insulation mat 69;
- iii) a fuel tank 70;
- iv) a fuel tube 71;
- v) a valve 72;
- vi) voltage regulating electronics 73; and
- vii) the electrical cable 74 connection to the portable computer 67.

The fuel cell power supply 66 may also be used to charge a battery 131 located in the portable computer 67. The fuel cell array 68 is placed along the back of the display screen 129 of the personal computer 67 and is protected by the ABS plastic housing 127, as shown. The fuel cell 66 is placed at this location to take advantage of the heat generated by the display screen 129 to elevate the operating temperature of the fuel cell and keep the heat and moisture generated by the fuel cell convected away from the user. A gas diffusion mat 69, made from polyester fiber paper to serve as a protective cover, is placed over the MICRO-FUEL CELL array 68 inside the ABS plastic housing 127. The gas diffusion mat 69 also serves as a thermal insulation layer. In cold environments it may be made thicker and in hot environments it may be made thinner to maintain an optimum elevated operating temperature of the MICRO-FUEL CELL array 68.

The fuel cavity is designed to have the fuel tank 70 underneath the portable computer, as shown in Figure 12. The fuel tank 70 may be protected by an ABS plastic cover, or it may be made robust enough that a cover is not needed. This

places the majority of the mass of the fuel cell power supply 66 as low as possible on the portable computer 67 to maintain a low center of gravity. The fuel tank 70 also provides good thermal conductivity to dissipate heat generated by the computer. The fuel tank 70, which is shaped to fit and grip the underside of the portable computer, is made from polyethylene plastic or polycarbonate plastic and filled with 1:1 molecular ratio of methanol to water mixture. The fuel tank 70 is made to be snapped to the underside of the portable computer 67 or to attach with other possible attachment mechanisms, such as Velcro, foam tape, slide-on, or screws. Fuel tanks 70 may be sold individually for replacement or may be refilled from a larger container of fuel. New fuel tanks 70 may have a membrane seal to ensure that no fuel leaks through the coupling before use.

Fueling is done by connecting the fuel tube 71 to the fuel tank 70. This fitting may be a screw on to a valve stem, a "quick connect", or a fuel needle insert type similar to a basketball rubber seal that seals on the shaft of the needle. The fuel is wicked, flowed or pumped from the needle or fuel connection to the MICRO-FUEL CELL fuel manifold. To allow observation of the fuel level in the fuel tank 70, a clear window 75 is built into the plastic housing 127. If a porous filler is used in the fuel tank, a change in the filler from transparent to opaque may be used to indicate the fuel level in the fuel tank. A dimpled area of the fuel tank 70 may be provided to pump the fuel to the fuel tube by alternately compressing and relieving pressure on the dimple. Since the portable computer power supply 66 is expected to run for periods of many hours before being shut down, a valve 72, which is connected to the fuel tube 71, is provided to shut off the fuel cell and save fuel from diffusion leakage through the fuel cell array 68. The fuel valve 72 may be opened and closed when the screen 133 of the computer 67 is opened and closed. The valve 72 may include capillaries to allow the fuel to wick through the valve. In

another embodiment, the fuel tube 71 is made out of a rubber or plastic such that when the display screen 133 is opened or shut, the capillaries are squeezed on and off, respectively. If one-way valves are used, simple pumping of the fuel may be achieved by opening and closing the display screen 133, or possibly by simply squeezing the fuel tube 71. The electric power from the fuel cell is delivered through voltage regulating circuitry 73 which is located next to the fuel cell array 68 or in the conventional battery cavity of the portable computer 67. Current flows from the fuel cell array 68 to the battery input connection 135 on the portable computer 67 through an electric cable 74. If a rechargeable battery is used, the electrical input may be at the common connection of the battery and the portable computer. The contact with the MICRO-FUEL CELL 68 can be made with rivet or other electrical connections. The fuel cell power supply 66 is carried as an integral part of the portable computer 67. It may have an outer porous cover to permit moisture from the fuel cell and the user's body to evaporate. The porous cover enhances the user's grip on the portable computer and makes it more comfortable to use.

The fuel cell power supply 76 is formed with ABS plastic housing 137 to fit and attach onto the exterior surfaces of a video camcorder or portable power tool battery 77, as shown in Figure 13. The fuel cell output is electrically connected in parallel to the rechargeable battery located in the camcorder or tool. The battery 77 may be a lead acid, nickel metal hydride or a lithium ion battery. With all those batteries, voltage regulation of the output may be used. For a lithium ion battery, the voltage regulation and charging circuit may automatically regulate the charging. The video camcorder or portable power tools are used for short periods of time, and then are idled for a period of time that ranges from hours to days. Thus, the fuel cell 76 trickle charges the battery 77 during the idle periods. The fuel cell array 78 is snapped along the back of the tool's battery 77, or

surrounds a smaller than usual battery, to allow this hybrid power supply to fit the docking cavity or arrangement on the video camcorder or portable power tool. The housing 137 of this hybrid power supply is made of ABS plastic. The fuel cell 76 is placed at this location to release the heat and moisture generated by the fuel cell 76 away from the video camcorder or portable power tool. A gas diffusion mat 79, made from polyester fiber paper to serve as a protective cover, is placed over the MICRO-FUEL CELL array 78 inside the ABS plastic housing 137. The gas diffusion mat 79 also serves as a thermal insulation layer. In cold environments it may be made thicker and in hot environments it may be made thinner to maintain an optimum elevated operating temperature of the fuel cell array 78. The fuel tank 80 is shaped to fit inside the power supply between the battery 77 and the diffusion mat 79. The fuel tank 80 is made from polyethylene plastic or polycarbonate plastic and filled with 1:1 molecular ratio of methanol to water mixture.

Fueling may be accomplished by snapping open the fuel cell power supply 76 from the battery 77, inserting the fuel tank 80, and closing the power supply assembly back over the battery. The fuel tank 80 is punctured by a fueling needle as the cover slides over the battery or could have screw on caps and screw onto the fuel cell. The fuel is then wicked from the needle or fuel connection to the fuel cell fuel manifold. The fuel tanks 80 may be sold individually or refilled by the user from a larger container of fuel. The fuel tanks 80 may also have a membrane seal to insure no fuel leakage through the coupling before use.

To allow observation of the fuel level in the fuel tank 80, the tank could be made clear with a window 81 in the plastic housing 137 for viewing. If a porous filler is used in the fuel tank, the change from transparent to opaque may also be the indicator of fuel quantity in the fuel tank 80. Electric power from the fuel cell is delivered through voltage regulating circuitry (not shown). Current flows from

the fuel cell array 78 to the video camcorder or portable power tool through two sheet metal contact strips 82, or by other electrical means, that form the common connection between the battery and video camcorder/power tool.

Electrical contact with the MICRO-FUEL CELL 78 is made through rivets or other electrical connections. The fuel cell to portable video camcorder or power tool power supply is carried as an integral part of the appliance. It may have an outer porous cover to permit moisture from the fuel cell and the user's body to evaporate. The porous cover enhances the user's grip on the appliance and makes it more comfortable to use.

A substitute for a piggy back charging scheme for video camcorders and portable power tools 83 is the separate fuel cell power supply 84, which is connected to the camcorder or tool through an electrical power cord, as illustrated in Figure 14. This permits a wide range of devices to be powered by the fuel cell 84, lightens the weight of the tool 83, and dissipates the heat of the fuel cell 84 away from the appliance 83. The fuel cell 84 may be carried as a strap-on or a clip-on by the user. The fuel cell output is electrically connected in parallel to the rechargeable battery 88, or is voltage regulated through electronics. The battery 88 may be a lead acid battery, nickel metal hydride or a lithium ion battery. With all of these battery chargings, voltage regulation of the output may be used. Especially if a lithium ion battery is used, the voltage regulation and charging circuit may regulate the charging. The video camcorder or portable power tools 83 are to run for short periods of time, and then are idled for hours to days. Thus, the fuel cell 84 trickle charges the battery during the idle periods. The housing of this power supply is made of ABS plastic. The fuel cell array 85 is placed at the outer surface to permit the intake of oxygen and the release of carbon dioxide, heat, and moisture generated by the fuel cell 84. Gas diffusion mats 86 and 139, made from polyester fiber

paper to serve as a protective covers, are placed around the fuel cell array 85 inside the ABS plastic housing. The gas diffusion mats 86 and 139 also serve as a thermal insulation layer. In cold environments it may be thickened, and in hot environments it may be thinned to maintain an optimum elevated operating temperature of the fuel cell array 85. The fuel tank 87 is shaped to fit inside the power supply assembly between the battery 88 and the inner diffusion mat 86. The outer diffusion mat 139 may be removed or changed. The fuel tanks 87 are made from polyethylene plastic or polycarbonate plastic and filled with 1:1 molecular ratio of methanol to water mixture. Fueling is done by snapping open the fuel cell from the assembly, inserting the fuel tank, and closing the fuel cell back over the assembly. The fuel tank is punctured on a fueling needle as the cover closes over the assembly. The fuel is then wicked, from the needle or fuel connection to the fuel cell fuel manifold. These large fuel tanks 87, which have a membrane seal to insure no fuel leakage through the coupling before use, may be sold individually or may be refilled by the user from a larger container of fuel. An alternative to the membrane seal might be to have a removable screw on cap that may be removed for attaching the fuel tank 87 to the fuel cell 85. To allow observation of the fuel quantity in the fuel tank 87, a clear window 89 or opening is provided to allow the fuel level to be viewed. If a porous filler is used in the fuel tank, the change from transparent to opaque indicates the fuel quantity in the fuel tank 87. Electric power from the fuel cell is delivered through a voltage regulating circuit next to the fuel cell. The current flows from the fuel cell array 85 to the video camcorder or portable power tool 83 through the electrical cable 90. The electrical contact with the fuel cell is made through rivets or other electrical connections.

The fuel cell to portable video recorder, or power tool power supply, is carried separate from the appliance. It may have an outer porous cover to permit moisture from the fuel

cell and the user's body to evaporate. The porous cover enhances the user's grip on the power supply and makes it more comfortable to use.

While this invention has been described in the context of a series of preferred embodiments, it will be apparent to those skilled in the art that the present invention may be modified in numerous ways and may assume many embodiments other than those specifically set out and described above. Accordingly, it is intended by the appended claims to cover all modifications of the invention which fall within the true spirit and scope of this invention.

We claim:

1. An apparatus having a power source for a battery powered device comprising an energy source, a MICRO-FUEL CELL array for receiving energy from the energy source, a diffusion mat positioned on the MICRO-FUEL CELL array, and a holder for receiving the battery powered device, the energy source, the diffusion mat, and the MICRO-FUEL CELL array.

2. The apparatus of claim 1, wherein the holder is of a plastic material.

3. The apparatus of claim 1, wherein the energy source is a fuel tank.

4. The apparatus of claim 3, wherein the fuel tank contains fuel that has a 1:1 molecular ratio of methanol to water.

5. The apparatus of claim 3, wherein the fuel tank is replaceable.

6. The apparatus of claim 3, further comprising a cavity in the holder for receiving the fuel tank.

7. The apparatus of claim 3, further comprising a fuel level indicator window in the holder for viewing the level of fuel in the fuel tank.

8. The apparatus of claim 1, further comprising locating electronics in the holder for locating the portable battery charger and battery powered device.

9. The apparatus of claim 1, further comprising power conditioning electronics in the holder.

10. The apparatus of claim 1, further comprising a clip on the holder for attaching the holder to a user's clothing.

11. The apparatus of claim 1, further comprising a ratchet mechanism for releasably securing the battery powered device to the holder.

12. The apparatus of claim 1, wherein the diffusion mat has a thickness that varies across the MICRO-FUEL CELL array.

13. The apparatus of claim 1, further comprising a cover for covering the holder.

14. The apparatus of claim 1, wherein the MICRO-FUEL CELL array is a surface replica fuel cell power source.

15. The apparatus of claim 5, further comprising a package having a plurality of fuel tanks for replacing spent fuel tanks.

16. A portable fuel cell charger apparatus comprising a battery, a fuel tank positioned around the battery, a MICRO-FUEL CELL array positioned around the fuel tank, a gas diffusion mat positioned around the MICRO-FUEL CELL array, and a holder for receiving the battery, the fuel tank, the MICRO-FUEL CELL array and the diffusion mat.

17. The apparatus of claim 16, further comprising a fuel level indicator window in the holder for viewing the level of fuel in the fuel cell.

18. The apparatus of claim 16, wherein the holder is of a plastic material.

19. The apparatus of claim 16, further comprising first and second openings positioned in the holder.

20. The apparatus of claim 19, further comprising first and second end caps positioned at the first and second openings of the holder.

21. The apparatus of claim 20, further comprising first and second pairs of clamps proximal the first and second openings of the holder for securing the first and second end caps to the holder.

22. The apparatus of claim 21, further comprising a spring on each of the first and second end caps for delivering power to the battery.

23. The apparatus of claim 16, further comprising ventilation holes in the holder.

24. The apparatus of claim 16, wherein the MICRO-FUEL CELL array is a surface replica fuel cell power source.

25. A portable fuel cell power supply apparatus comprising an energy source, a MICRO-FUEL CELL array for receiving energy from the energy source, a gas diffusion mat positioned on the MICRO-FUEL CELL array, a battery for

receiving a continuous trickle charge from the MICRO-FUEL CELL array, and a holder for receiving the energy source, the MICRO-FUEL CELL array, the diffusion mat and the battery.

26. The apparatus of claim 25, wherein the energy source is a fuel tank.

27. The apparatus of claim 26, wherein the fuel tank contains fuel that has a 1:1 molecular ratio of methanol to water.

28. The apparatus of claim 26, wherein the fuel tank is refillable.

29. The apparatus of claim 25, wherein the holder fits into the battery cavity of a cellular phone.

30. The apparatus of claim 25, wherein the holder is of a plastic material.

31. The apparatus of claim 26, further comprising a cavity in the holder for receiving the fuel tank.

32. The apparatus of claim 26, further comprising a fuel level indicator window in the holder for viewing the level of fuel in the fuel tank.

33. The apparatus of claim 25, wherein the diffusion mat has a thickness that varies across the MICRO-FUEL CELL array.

34. The apparatus of claim 25, further comprising a cover for covering the holder.

35. The apparatus of claim 28, further comprising a refill port in the holder for adding fuel to the fuel tank.

36. The apparatus of claim 35, further comprising a fuel dispenser for adding fuel to the fuel tank through the refill port.

37. The apparatus of claim 25, wherein the MICRO-FUEL CELL array is a surface replica fuel cell power source.

38. The apparatus of claim 28, wherein the fuel tank is replaceable.

39. The apparatus of claim 38, further comprising a kit having a plurality of fuel tanks for replacing spent fuel tanks.

40. A cellular phone battery charger apparatus comprising an energy source, a MICRO-FUEL CELL array for receiving energy from the energy source, a gas diffusion mat positioned on the MICRO-FUEL CELL array, a holder for receiving the MICRO-FUEL CELL array, the diffusion mat, and a cellular phone, and a housing for receiving the holder and the energy source.

41. The apparatus of claim 40, wherein the energy source is a fuel tank.

42. The apparatus of claim 40, wherein the fuel tank contains fuel that has a 1:1 molecular ratio of methanol to water.

43. The apparatus of claim 41, wherein the fuel tank is refillable.

44. The apparatus of claim 41, further comprising a fuel level indicator window in the housing for viewing the level of fuel in the fuel tank.

45. The apparatus of claim 43, further comprising a refill port in the housing for adding fuel to the fuel tank.

46. The apparatus of claim 41, wherein the fuel tank is replaceable.

47. The apparatus of claim 46, further comprising a kit having a plurality of fuel tanks for replacing spent fuel tanks.

48. A portable computer power supply apparatus comprising an energy source, a MICRO-FUEL CELL array for receiving energy from the energy source, a gas diffusion mat positioned on the MICRO-FUEL CELL array, a housing for receiving the energy source, MICRO-FUEL CELL array, and gas diffusion mat and for connecting to the exterior of a portable computer, and a cable connecting the portable computer to the housing for supplying power to the personal computer.

49. The apparatus of claim 48, wherein the energy source is a fuel tank.

50. The apparatus of claim 49, further comprising a tube for supplying fuel from the fuel tank to the MICRO-FUEL CELL array.

51. The apparatus of claim 50, further comprising a valve in the tube for controlling flow of fuel to the MICRO-FUEL CELL array.

52. The apparatus of claim 48, further comprising voltage regulating electronics connected to the housing for regulating power supplied to the portable computer.

53. The apparatus of claim 48, wherein the diffusion mat has a thickness that varies across the MICRO-FUEL CELL array.

54. The apparatus of claim 48, wherein the housing further comprises first and second parts, wherein the first part houses the energy source and fits beneath the keyboard of a portable computer and the second part houses the MICRO-FUEL CELL array and the diffusion mat and fits behind the screen of the portable computer.

55. The apparatus of claim 49, wherein the fuel tank contains fuel that has a 1:1 molecular ratio of methanol to water.

56. The apparatus of claim 49, wherein the fuel tank is refillable.

57. The apparatus of claim 49, further comprising a fuel level indicator window in the housing for viewing the level of fuel in the fuel tank.

58. The apparatus of claim 56, further comprising a refill port in the housing for adding fuel to the fuel tank.

59. The apparatus of claim 49, wherein the fuel tank is replaceable.

60. The apparatus of claim 59, further comprising a kit having a plurality of fuel tanks for replacing spent fuel tanks.

61. The apparatus of claim 48, further comprising a cover for covering the housing.

62. A portable battery power supply apparatus comprising an energy source, a MICRO-FUEL CELL array for receiving energy from the energy source, a gas diffusion mat positioned on the MICRO-FUEL CELL array, a housing for receiving the energy source, MICRO-FUEL CELL array, and gas diffusion mat and for connecting to a portable battery, and plural connections for supplying power from the MICRO-FUEL CELL array to the portable battery.

63. The apparatus of claim 62, wherein the energy source is a fuel tank.

64. The apparatus of claim 62, wherein the plural connections are sheet metal contact strips.

65. The apparatus of claim 62, wherein the diffusion mat has a thickness that varies across the MICRO-FUEL CELL array.

66. The apparatus of claim 63, wherein the fuel tank contains fuel that has a 1:1 molecular ratio of methanol to water.

67. The apparatus of claim 63, wherein the fuel tank is refillable.

68. The apparatus of claim 63, further comprising a fuel level indicator window in the housing for viewing the level of fuel in the fuel tank.

69. The apparatus of claim 67, further comprising a refill port in the housing for adding fuel to the fuel tank.

70. The apparatus of claim 63, wherein the fuel tank is replaceable.

71. The apparatus of claim 70, further comprising a kit having a plurality of fuel tanks for replacing spent fuel tanks.

72. The apparatus of claim 62, wherein the diffusion mat is placed between the energy source and the MICRO-FUEL CELL array.

73. The apparatus of claim 62, further comprising voltage regulating electronics connected to the housing for regulating power supplied to the portable battery.

74. The apparatus of claim 62, further comprising a cover for covering the housing.

75. A battery-powered portable device power supply apparatus comprising an energy source, a MICRO-FUEL CELL array for receiving energy from the energy source, a gas diffusion mat positioned on the MICRO-FUEL CELL array, a battery for receiving energy from the MICRO-FUEL CELL array, a housing for receiving the energy source, MICRO-FUEL CELL array, gas diffusion, and battery, and a connection for supplying power from the battery to the battery-powered portable device.

76. The apparatus of claim 75, wherein the energy source is a fuel tank.

77. The apparatus of claim 75, wherein the connection is an electrical power cord.

78. The apparatus of claim 75, wherein the diffusion mat has a thickness that varies across the MICRO-FUEL CELL array.

79. The apparatus of claim 76, wherein the fuel tank contains fuel that has a 1:1 molecular ratio of methanol to water.

80. The apparatus of claim 76, wherein the fuel tank is refillable.

81. The apparatus of claim 76, further comprising a fuel level indicator window in the housing for viewing the level of fuel in the fuel tank.

82. The apparatus of claim 76, further comprising a refill port in the housing for adding fuel to the fuel tank.

83. The apparatus of claim 76, wherein the fuel tank is replaceable.

84. The apparatus of claim 76, further comprising a kit having a plurality of fuel tanks for replacing spent fuel tanks.

85. The apparatus of claim 75, further comprising voltage regulating electronics connected to the housing for

regulating power supplied to the battery-powered portable device.

86. The apparatus of claim 75, further comprising a cover for covering the housing.

87. A MICRO-FUEL CELL manufacturing method comprising providing porous plastic film, rolling the film onto a source reel, inserting the film from the source reel into a web coating vacuum chamber, coating the film while the film reels past deposition sources within the vacuum chamber, removing heat from the film through the use of heat sinks within the vacuum chamber, reeling the film out of the vacuum chamber and onto a take-up reel, reeling the film through an electrolyte solution, and drying and heat curing the film in an oven.

88. The method of claim 87, further comprising advancing, adjusting and stopping the film with position rollers for deposition.

89. The method of claim 87, wherein coating the film further comprises depositing high pressure sputtered Pt/Ru, then low pressure sputtered Pd, and then high pressure sputtered Pt/Ru on a first side of the film, and then depositing low pressure Au and then high pressure Pt/Ru on a second side of the membrane.

90. A MICRO-FUEL CELL power method comprising providing an energy source, supplying energy from the energy source to a MICRO-FUEL CELL array, positioning a gas diffusion mat, providing a housing for receiving the energy source, MICRO-FUEL CELL array, and gas diffusion mat.

91. The method of claim 90, further comprising storing the energy from the MICRO-FUEL CELL array in a battery contained in the housing, connecting the battery to a portable battery-powered device, and supplying energy from the battery to the portable battery-powered device.

92. The method of claim 91, further comprising measuring fuel level selected from a group consisting of a weight monitoring system, an electrical capacitance system, a

chemical coloring system wherein color or opacity of the chemical changes as fuel is depleted, a fuel immobilizer matrix wherein as fuel is replaced with gas the opacity of the fuel changes, and a float indicator.

93. The apparatus of claim 3, wherein the fuel tank contains fuel having a hydrogen bearing compound.

94. The apparatus of claim 93, wherein the fuel is selected from a group consisting of alcohol and hydrocarbon bearing compounds.

95. The apparatus of claim 42, wherein the fuel tank contains fuel having a hydrogen bearing compound.

96. The apparatus of claim 96, wherein the fuel is selected from a group consisting of alcohol and hydrocarbon bearing compounds.

97. The apparatus of claim 55, wherein the fuel tank contains fuel having a hydrogen bearing compound.

98. The apparatus of claim 97, wherein the fuel is selected from a group consisting of alcohol and hydrocarbon bearing compounds.

99. The apparatus of claim 66, wherein the fuel tank contains fuel having a hydrogen bearing compound.

100. The apparatus of claim 99, wherein the fuel is selected from a group consisting of alcohol and hydrocarbon bearing compounds.

101. The apparatus of claim 79, wherein the fuel tank contains fuel having a hydrogen bearing compound.

102. The apparatus of claim 101, wherein the fuel is selected from a group consisting of alcohol and hydrocarbon bearing compounds.

103. The method of claim 87, wherein the coating the film while the film reels past deposition sources is selected from a group consisting of sputtering, evaporation, chemical vapor deposition, spray painting, ink jet painting, proximity electroplating, xerography, photolithography, and auto electroplating.

FIG. 1A

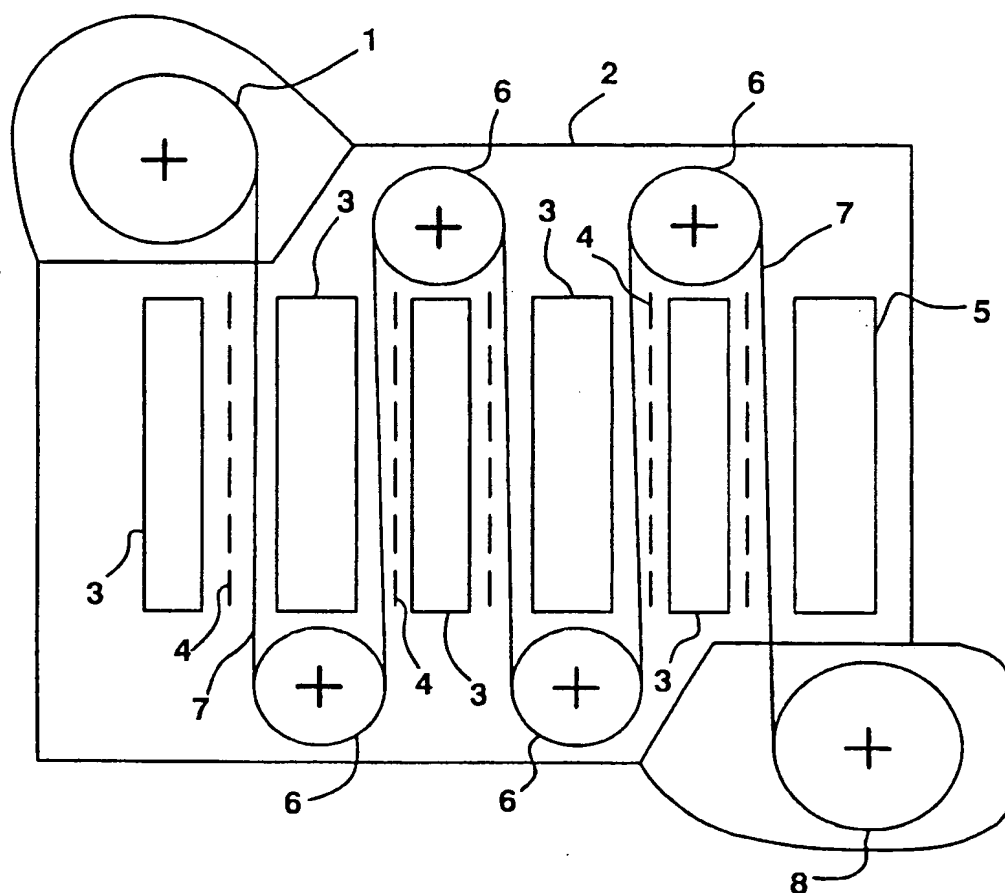
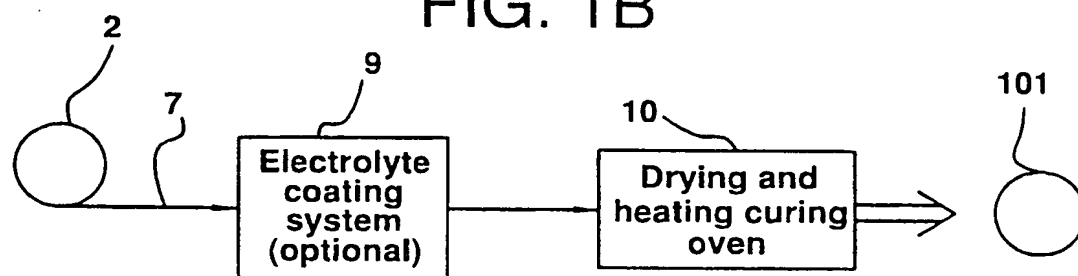


FIG. 1B



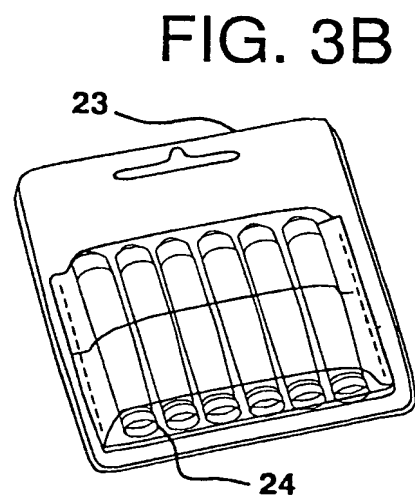
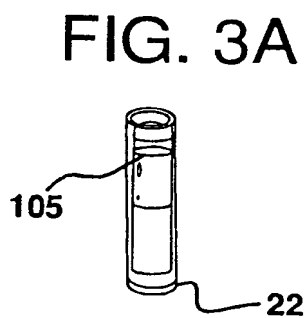
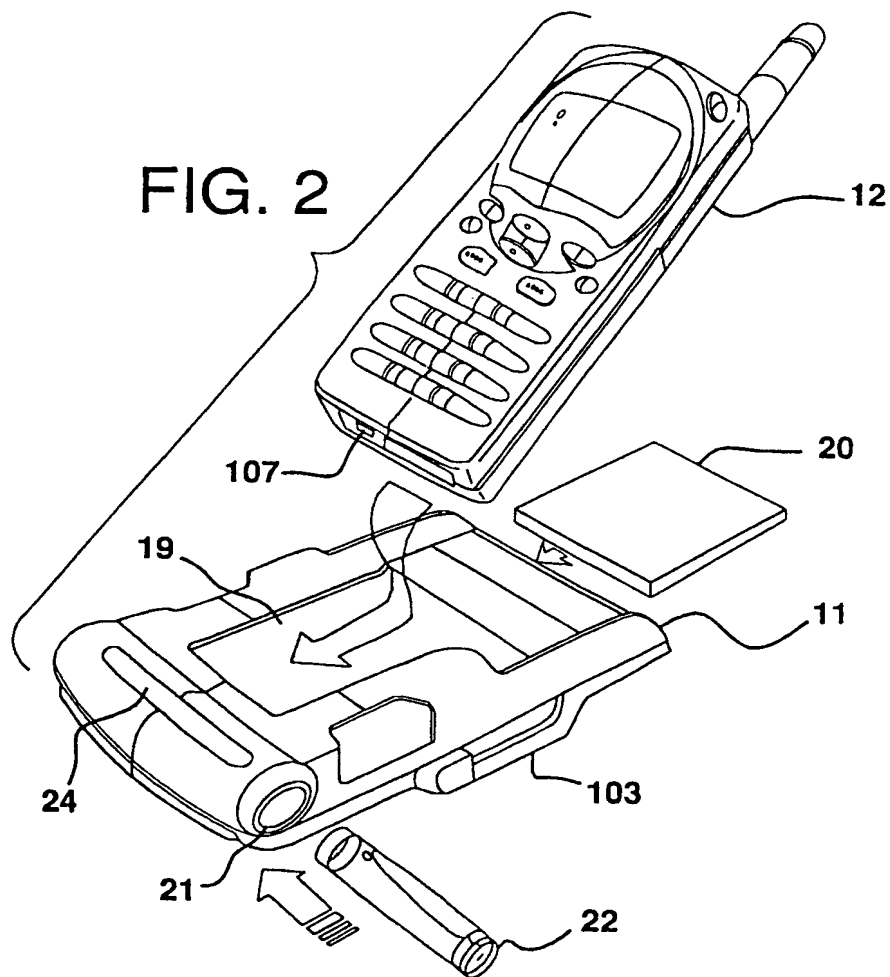


FIG. 4A

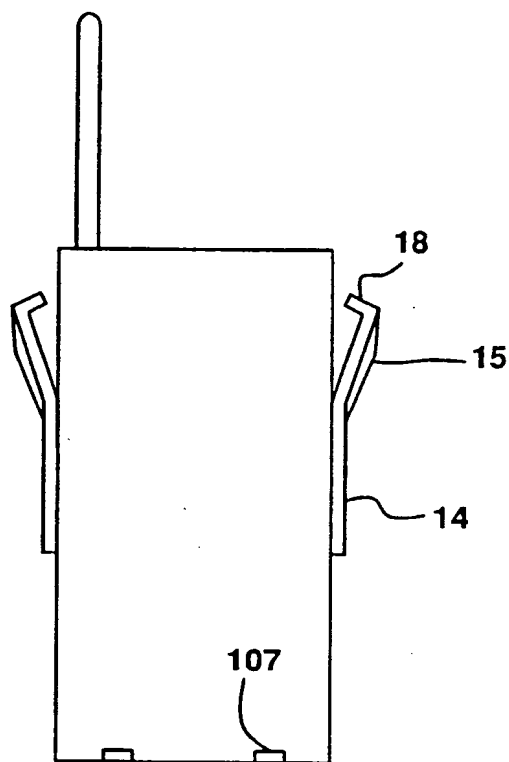


FIG. 4B

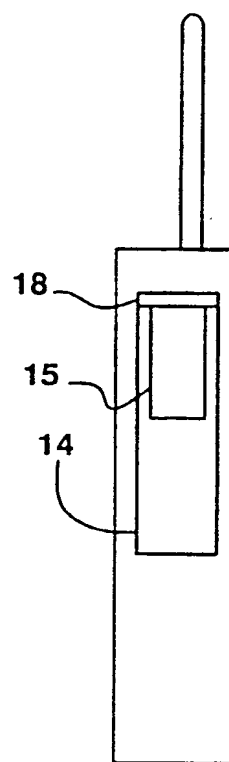


FIG. 4C

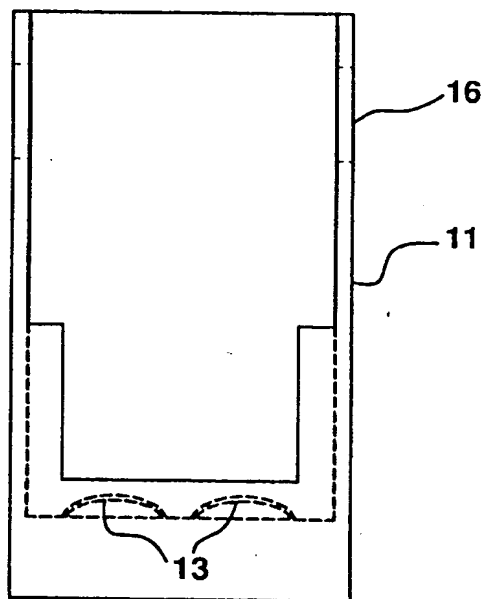


FIG. 4D

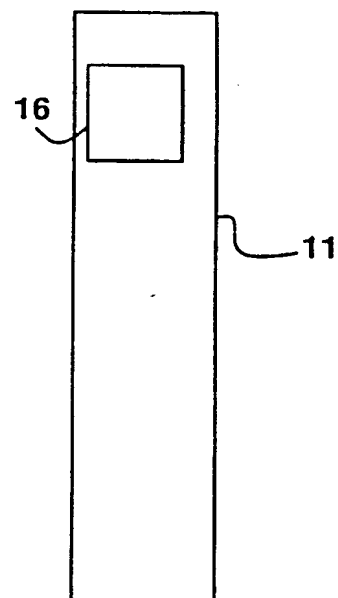


FIG. 5A

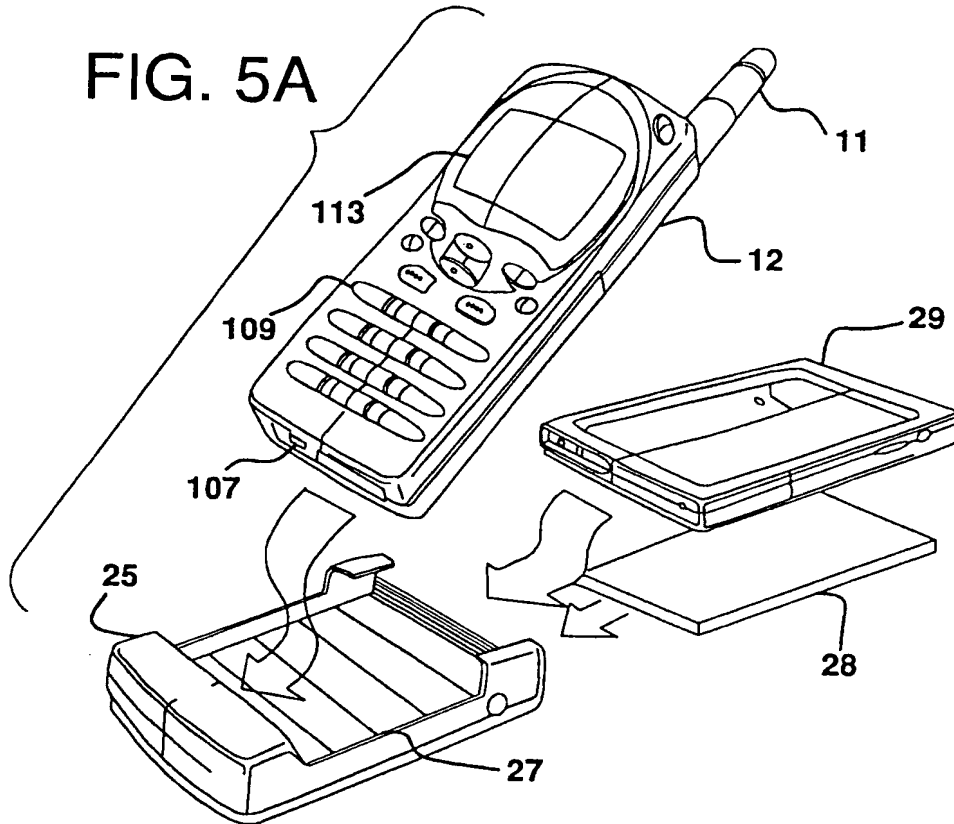


FIG. 5B

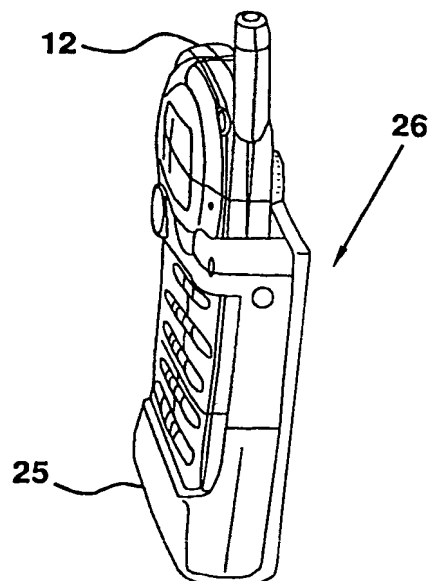


FIG. 6A

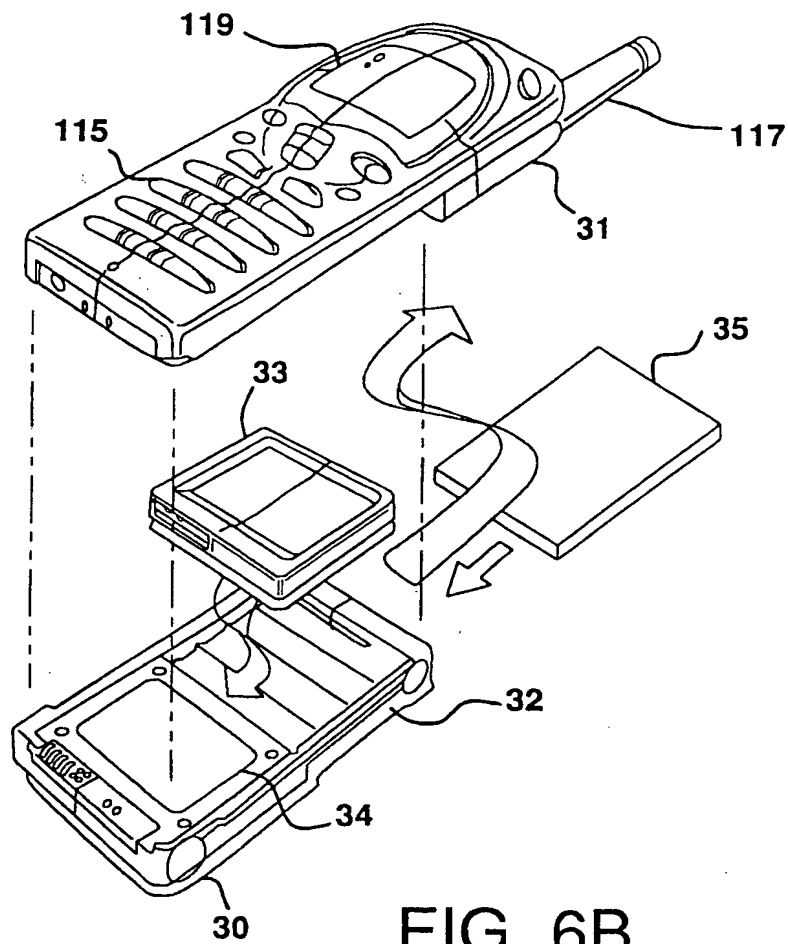


FIG. 6B

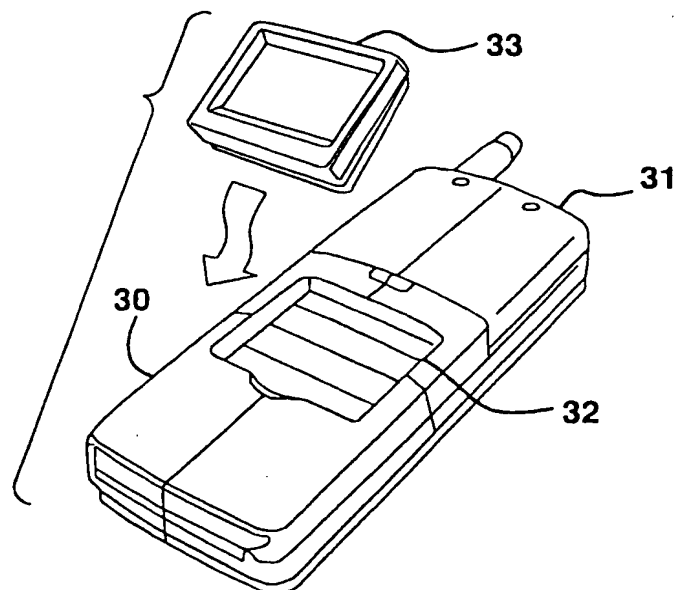


FIG. 7A

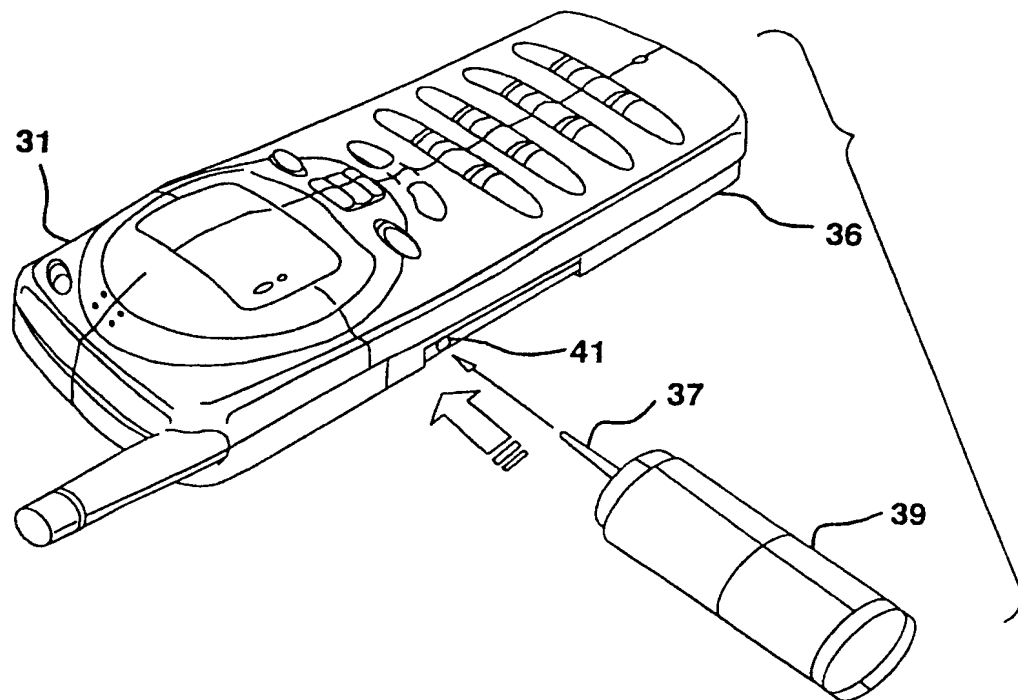


FIG. 7B

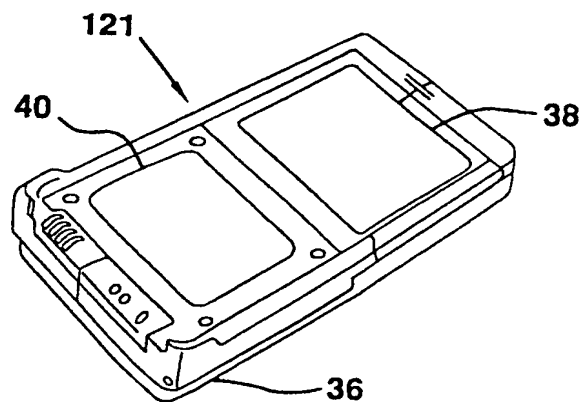


FIG. 8A

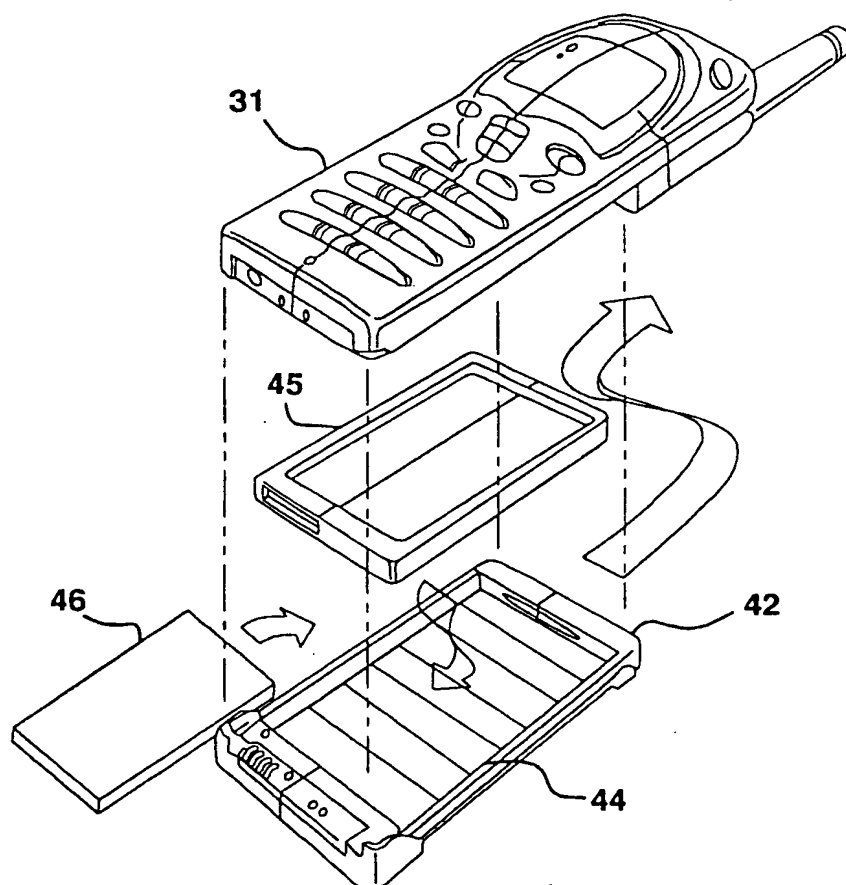


FIG. 8B

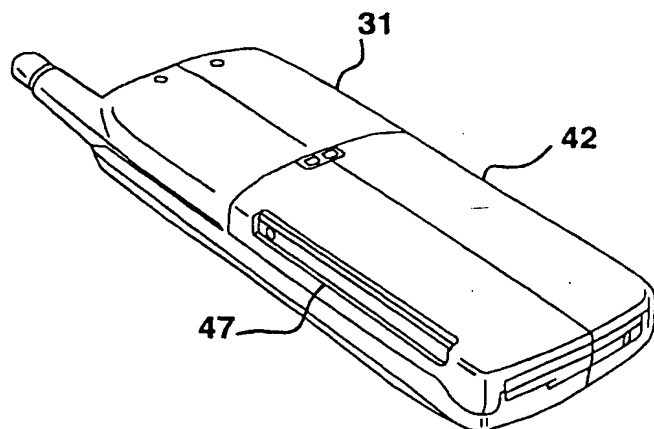


FIG. 9

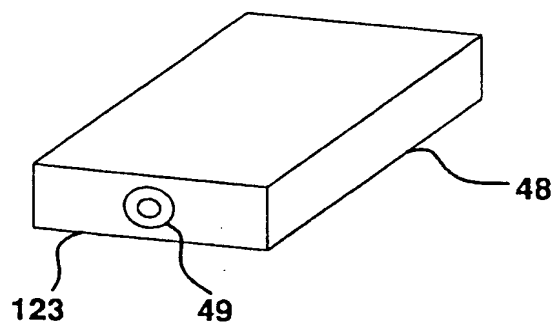


FIG. 10

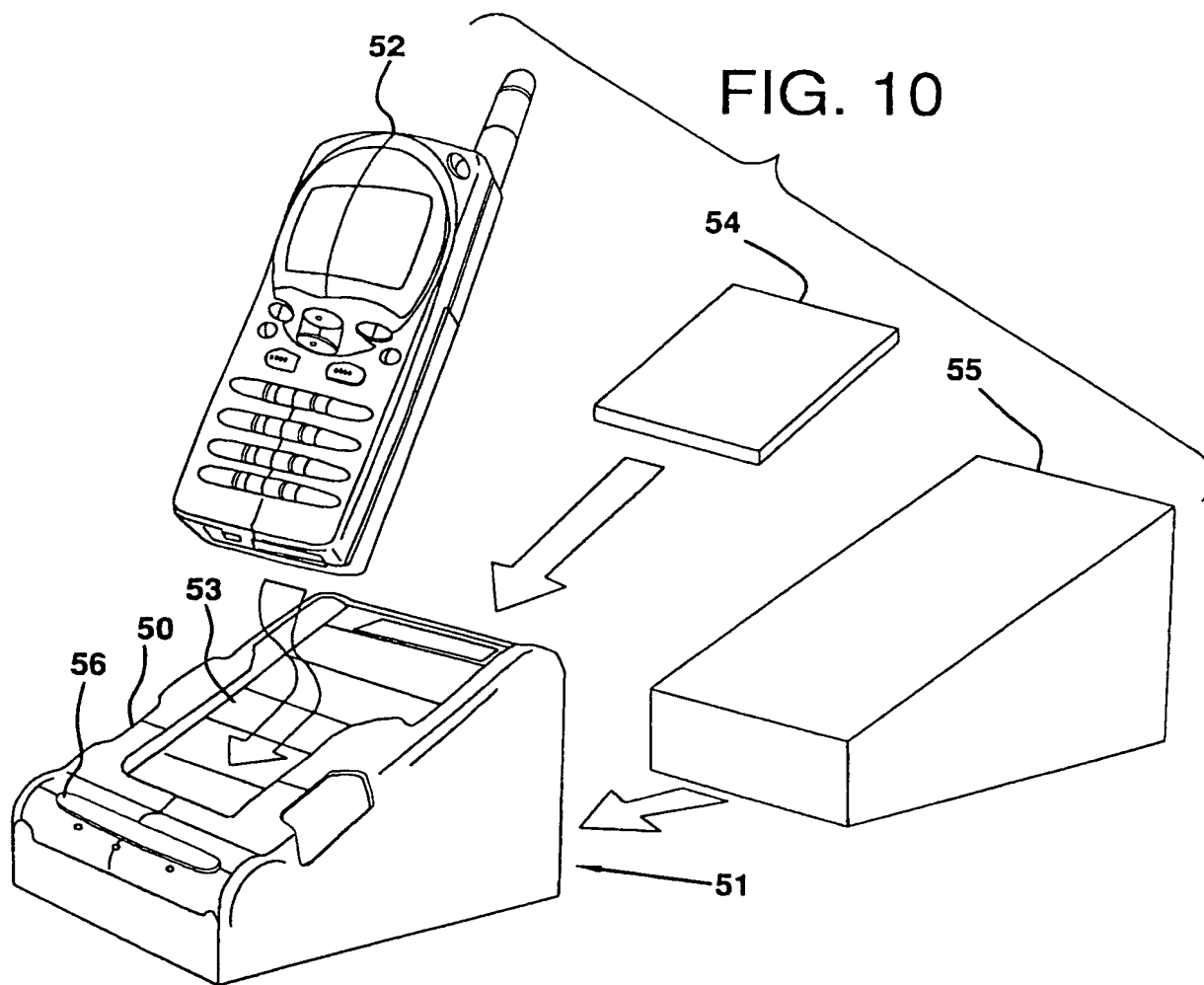


FIG. 11

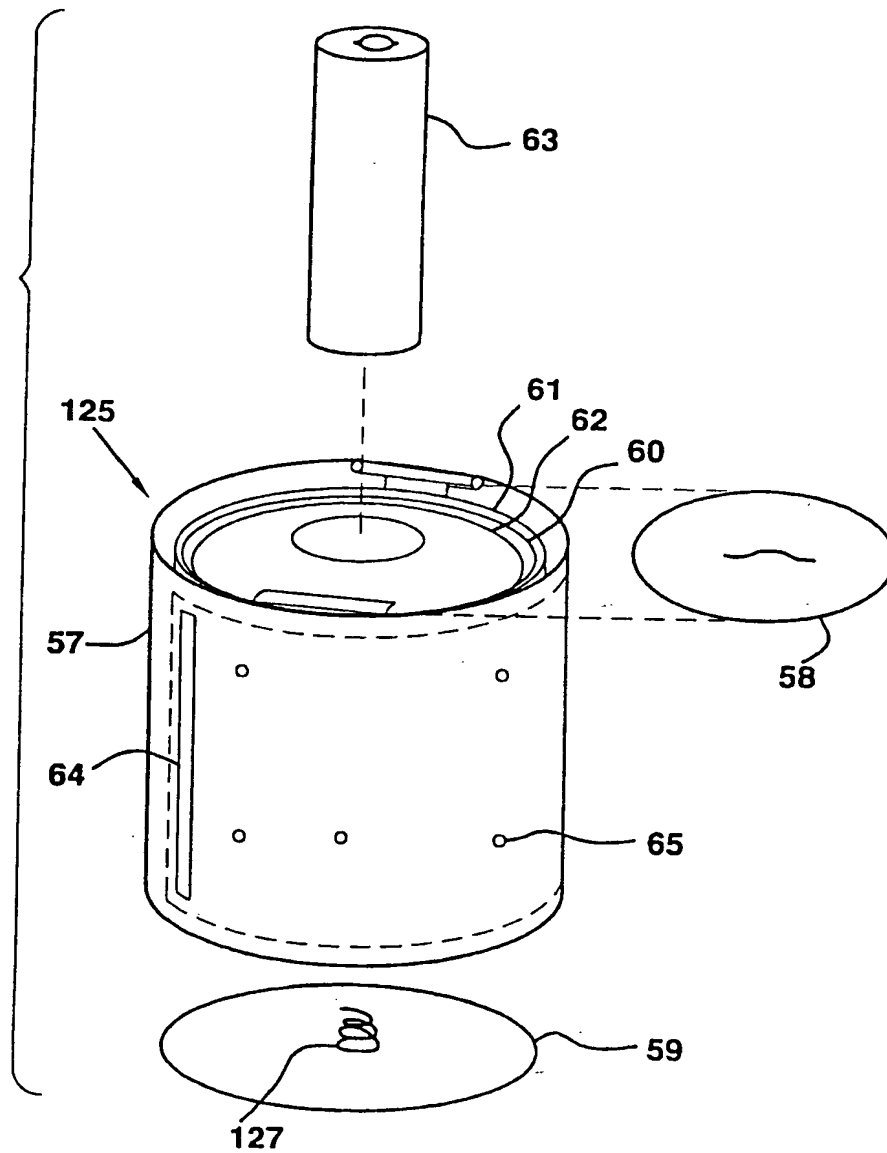


FIG. 12

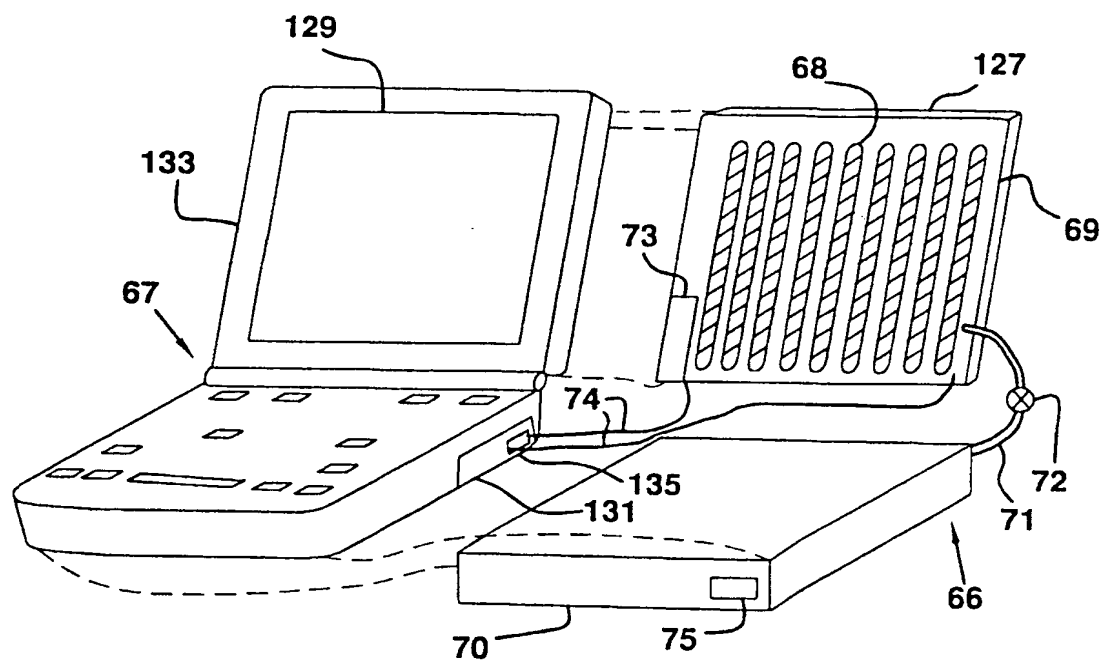


FIG. 13

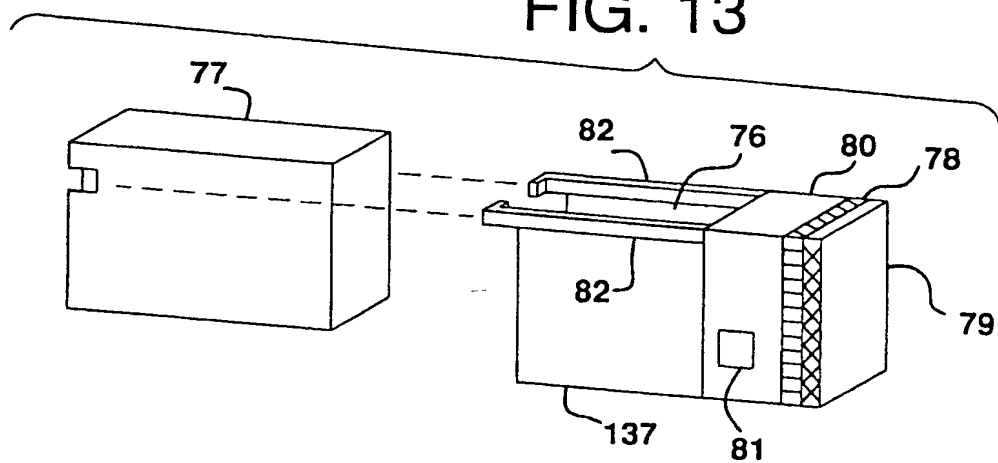
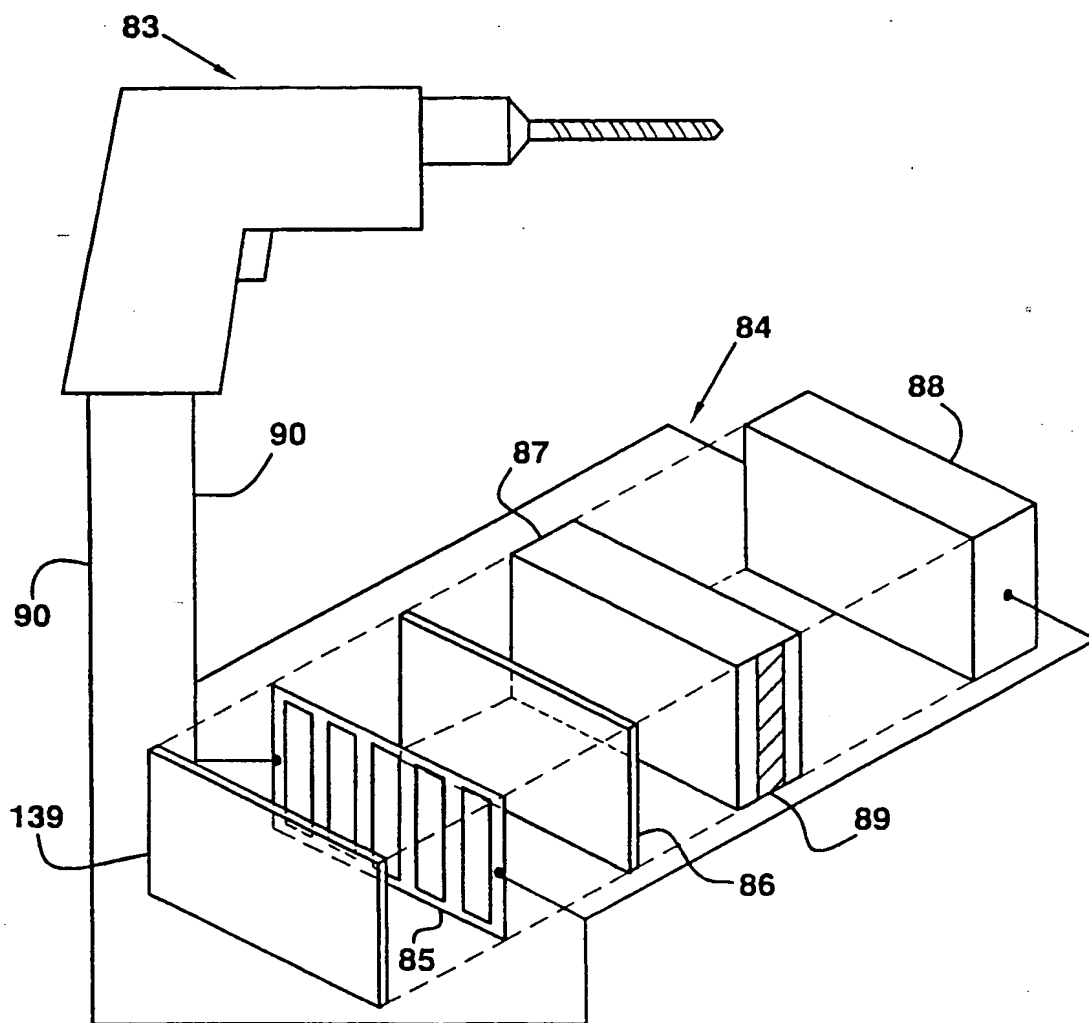


FIG. 14



INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/29350

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : H01M 02/00, 08/10, 02/08, 10/48

US CL : 429/30, 34, 37, 91

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 429/30, 34, 37, 91

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
WEST, EAST

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,641,585 A (LESSING et al) 24 June 1997, see the whole document.	1-103
Y	US 4,294,891 A (YAO et al) 13 October 1981, abstract, col. 5, line 25 to col. 7, line 27.	1-39, 62-94, 96 & 103
Y	US 5,432,023 A (YAMADA et al) 11 July 1995, col 8, line 31 to col 12, line 68.	1-39, 62-94, 96 & 103
A	US 4,650,727 A (VANDERBORGH et al) 17 March 1987.	1-39, 87-92, 103
A	US 5,470,670 A (YASUMOTO et al) 28 November 1995.	1-39, 89-92, 103
A	US 5,342,703 A (KAWASAKI et al) 30 August 1994.	1-39, 89-92, 103

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E" earlier document published on or after the international filing date	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&" document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

17 MARCH 2000

Date of mailing of the international search report

04 APR 2000

Name and mailing address of the ISA/US
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Telephone No. (703) 308-0661

Form PCT/ISA/210 (second sheet)(July 1992)*

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/29350**Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)**

This international report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

Please See Extra Sheet.

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☒ The additional search fees were accompanied by the applicant's protest.
☐ No protest accompanied the payment of additional search fees.

Form PCT/ISA/210 (continuation of first sheet(1))(July 1992)★

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/29350

BOX II. OBSERVATIONS WHERE UNITY OF INVENTION WAS LACKING

This ISA found multiple inventions as follows:

This application contains the following inventions or groups of inventions which are not so linked as to form a single inventive concept under PCT Rule 13.1. In order for all inventions to be searched, the appropriate additional search fees must be paid.

In addition, this application contains claims directed to more than one species of the generic invention. These species are deemed to lack of Unity of Invention because they are not so linked as to form a single inventive concept under PCT Rule 13.1. In order for more than one species to be searched, the appropriate additional search fees must be paid.

Group I, claim(s) 1-15, 93-94 and 96, drawn to an apparatus having a power source for a battery powered device.

Group II, claim(s) 16-24, drawn to a portable fuel cell charger apparatus.

Group III, claim(s) 25-39, drawn to a portable fuel cell power supply apparatus.

Group IV, claim(s) 40-47 and 95, drawn to a cellular phone battery charger apparatus.

Group V, claim(s) 48-61 and 97-98, drawn to a portable computer power supply apparatus.

Group VI, claim(s) 62-74 and 99-100, drawn to a portable battery power supply apparatus.

Group VII, claim(s) 75-86 and 101-102, drawn to a battery powered portable device power supply apparatus.

Group VIII, claim(s) 87-89 and 103, drawn to a micro fuel cell manufacturing method.

Group IX, claim(s) 90-92, drawn to a micro fuel cell power method.

The inventions listed as Groups I-VII, Group VIII and Group IX do not relate to a single inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons: the special technical feature, i.e. "the micro fuel cell" is known as evidenced by US 5641585.

The species listed above (Groups I-VII) do not relate to a single inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, the species lack the same or corresponding special technical features for the following reasons: the special technical feature, i.e. "the micro fuel cell" is known as evidenced by US 5641585.